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MEMORANDUM

To: Russ Larson

From: Donald Eyles

Subject: Altitude-rate error with EMP 103A

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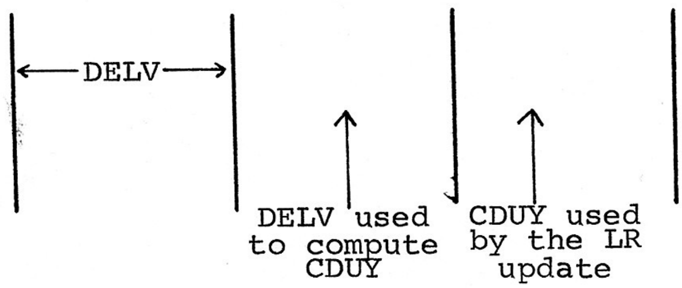
The error in altitude-rate encountered in landings with EMP 103A is due to errors in the CDUY computed by the EMP, which affect the state vector via the landing radar update routine. The update routine dots the platform velocity vector with a unit antenna vector which is in error by the CDUY error. The resulting scalar is compared to VMEAS and the difference, suitably weighted and multiplied by the unit antenna vector, is incorporated into the velocity vector. In the radial direction, the rate error thus introduced is porportional to the total velocity magnitude and to the sine of the angular error. For a one degree error in CDUY at a speed of 2000 f/s the radial rate error is on the order of 34 f/s. Fortunately, we do not expect there to be that much error in the CDUY computed by EMP 103A.

Two sources of error in the computed CDUY have been identified:

(1) The first stems from the fact that the computed CDUY lags behind the real angle by three seconds. The CDUY computed from the DELV vector is (roughly) valid for the middle of the PIPA interval over which that DELV was accumulated. This angle is computed by the EMP following Servicer during the next PIPA interval, and it is picked up and used by the next Servicer as if it were valid for <u>that</u> PIPTIME. In fact it is valid for a

time about three seconds before that. See the drawing, in which the vertical lines represent PIPTIMEs:



If pitch is flown smoothely during P63 the rate-of-change of pitch is about $-.1^{\circ}/s$, and thus the steady-state error from this source is about $.3^{\circ}$ in the wrong direction, i.e. though the mechanism described above it makes the AGC think the LM is descending more slowly than it actually is, by about 10 f/s. Simulations run at MIT bear out these numbers. For rough maneuvers, as when a man is flying N87, the error is less predictable but probably less because there will be periods when pitch is not changing at all and the velocity vector is being updated accurately.

(2) A second source of error is the fact that the thrust axis may not be parallel to the LM x-axis, as assumed by the EMP. This misalignment is due to the fact that the center-of-gravity does not lie on the x-axis, and it can be seen in the deflection of the trim gimbal. Since the altitude-rate error encountered in simulations run at the Cape reaches nearly 30 f/s, too much to be accounted for by time lag, thrust axis misalignment is thought to be partially responsible. Whether LMS or MIT simulations better reflect the true thrust axis misalignment is an open question.

Since CDUY error due to time lag is known not to be enough, by itself, to prejudice a landing, whether anything should be done about this problem depends on the thrust vector misalignment

anticipated. The following paragraphs describe what might be done if necessary.

Note that locking the trim gimbal at zero is <u>not</u> a solution. For the spacecraft to be controlled the total thrust vector <u>must</u> go through the center-of-gravity, and the DAP will fire jets to make it so if the gimbal is disabled. RCS jets as well as the DPS contribute to the DELV vector used by the EMP.

The landing radar update routine, where the error actually enters the state vector, is the most likely place to look for solutions. The weighting function might be changed to prevent velocity updates; the altitude radar functions properly, and the tape meter can be used as a gross check on altitude-rate. LRVMAX might be changed so that velocity updates only begin when speed has dropped below some value; changing LRVMAX to octal 00303, for instance, would prevent velocity updates until velocity is below 500 f/s. Oddly enough, a possible alternative is to increase the weight given to velocity updates. This will not make the error any worse, although maximum error will be reached sooner, and will cause it to be corrected faster as speed drops. These ideas as yet have not been tested.

Another possibility is simply to monitor the AGC altitude-rate and compare it to values from the Lear processor or the AGS in order to warn the crew that an early manual takeover will be necessary to have sufficient flying room above the Moon. The table on the following page, compiles from runs with CDUY errors from various causes, hopefully will show how bad the altitude-rate build-up must be in P63 before the conditions at the P66 takeover point are degraded. All runs were made on the digital simulator with the Apollo 17 mass properties but no initial state vector errors. All these runs benefitted from the fact that velocity radar acquisition occurred at a LM speed of approximately 1000 f/s. An earlier lock-on would have made the situation worse.

	CDUY error (Env - AGC)	At velocity data good		At maximum altrate error			1000 feet		500 feet	
		Altitude	Speed	Altrate error	Altitude	Speed	Altrate (Env)	Altrate (AGC)	Altrate (Env)	Altrate (AGC)
EMP 103A computes CDUY used by LR	$-.3^{\circ}+$	17271	1045	-18	14402	753	-35	-36	-17	-17
CDUY error induced artificially	-1.3°	17491	1025	-11	15619	701	-37	-36	-18	-17
CDUY error induced artificially	$+2.2^{\circ}$	16839	1044	+25	14115	668	-33	-39	-21	-25
CDUY error induced artificially	-3.5°	17804	1026	-43	12073	624	-69	-51	-46	-32
CDUY error induced artificially	-4.0°	17444	1012	-46	14170	676	-71	-52	-52	-35